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Abstract
Purpose – The purpose of this paper is to understand the configuration of a job production system with reference to manufacturing decision areas. The aim is to identify the process specific decisions for job shop and the non-process specific decisions that are influenced by other contextual factors.

Design/methodology/approach – A case study research approach is used in the present paper to investigate the decisions of five manufacturing companies that satisfy the characteristics of job production system. Data are collected from case company's products, order winners and choices made in manufacturing decision areas. The paper uses within case and cross-case analysis to identify various patterns in the data, with a view to meeting the required research objectives.

Findings – The present paper identifies a number of decisions specific to job shop. Further, many non-process specific decisions are seen to be influenced by competitive priorities (order winner), strategic orientation of manufacturing (stages in H-W model), top management and size of the company. After the study of the case companies, it is also observed that the companies employing a job production system may have high product complexity.

Practical implications – The findings derived from this research would facilitate practitioners in understanding both process specific and non-process specific decisions for the job production system. The observation that the job shops can also use progressive practices, the same as other shops, to gain competitive advantage in the market could be very useful for practicing managers.

Originality/value – This exploratory research contributes to the existing theory in manufacturing decision areas for job production systems.

Keywords India, Job production systems, Decision making, Manufacturing systems, Manufacturing strategy, Manufacturing decision areas, Case studies

Paper type Research paper

1. Introduction
Skinner (1969) characterized manufacturing strategy as consisting of a pattern of many individual decisions that provide the required competence for a firm. The competence is an ability of the firm to excel in competitive priorities such as cost, quality, delivery,

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flexibility and innovation (Safizadeh *et al.*, 2000). Providing the required competence in the marketplace is the job of a production system and it depends upon the configuration of many individual decisions. These decisions are organized into a framework called "decision areas". Hayes and Wheelwright (1984) have classified the decision areas into two groups: structural and infrastructural. Decision areas include human resources, organization structure and control; and production planning and control (PPC) as infrastructural decisions whereas sourcing, process technology and facilities as structural decisions.

Most widely used generic production systems in literature are job, batch, line and continuous flow (Hayes and Wheelwright, 1979a, b). This classification of production system is related to product volume and varieties. Manufacturing literature cites studies in decision areas (Skinner, 1969; Wheelwright, 1984; Fine and Hax, 1985; Garrido *et al.*, 2007); but these do not differentiate studies based on process choice. Few authors (Woodward, 1965; Hull and Collins, 1987) have studied composition of production system on a limited number of elements of decision areas. However, Miller (1981) states that the same relationship between variables may not generally hold in different contexts (e.g. process choice, market). Thus, it is desirable to control the process choice in such studies. Safizadeh *et al.* (2000) argue that controlling the process choice offers a new perspective on alternative manufacturing paradigms and that tradeoffs are implicit in the process choice itself.

Manufacturing strategy literature cites studies that provide description of decisions made under each process choice based on conceptual or empirical research (Ashton and Cook, 1989; Safizadeh and Ritzman, 1997; Olhager and Rudbergy, 2002; Olhager *et al.*, 2001; Hill and Hill, 2009; Miltenburg, 2005). However, the list of decisions considered in these studies is not comprehensive.

Various studies in manufacturing decision areas suggest that decision choices are not always process specific but are influenced by several other factors. Some studies (Bhattacharya and Coleman, 1994; Spring and Dalrymple, 2000; Garrido *et al.*, 2007) point out that decision such as planning strategy and master planning schedule are related to product complexity. A four-stage model (H-W model) proposed by Wheelwright and Hayes (1985) states that companies in different stages of strategic orientation of manufacturing, exhibit different preferences in their decision choices. A research on manufacturing performance suggests that decision choices are related to the competitive priorities of the firms (Safizadeh and Ritzman, 1997; Vickery *et al.*, 1999; Narasimhan and Das, 1999; Olhager *et al.*, 2001). In some companies, decisions are made by top management for reasons such as convenience in location decision and ability to invest in deciding the size of operation (Schmenner, 1979; Slack and Lewis, 2009). Once these decisions are made, they may influence other decisions. For instance, the size of the company is also found to influence many other decisions in production system (Cagliano and Spina, 2000; Swamidass and Kotha, 1998; Spring and Dalrymple, 2000). It is essential to understand how these factors affect decision choices in order to develop a sound manufacturing strategy. There is paucity of empirical research in this area. It is worth knowing decisions that are specific to process choice and decisions that are contingent on other factors discussed above. Research in this line will also lead to the possibility of some competent configurations in any type of production system that might be useful in practice. The present work is a first attempt of this kind and it focuses on job shop production system.

This research paper aims to investigate the decision choices made in job production system by exploring five case studies. The following are the explicit research objectives of the study. The first objective is to explore process specific decisions with respect to job production system. The second objective is to identify non-process specific decision choices that are influenced by other factors. The factors considered in this study are product complexity, competitive priorities (order winner), strategic orientation of manufacturing (stages in H-W model), top management and size of the company.

The paper is structured in six sections. Section 2 briefly reviews the relevant literature and develops the research framework for this study. The research methodology is discussed in Section 3. In Section 4, with-in case and cross-case analyses are presented for five case companies. Conclusions and future work are discussed in Section 5.

2. Literature review

In this section, we initially present the review of literature on manufacturing decision areas. This is followed by the review of research on process specific decisions in job production system and non-process specific decisions.

2.1 Manufacturing decision areas

On a broad level, manufacturing decision areas comprise structural and infrastructural decisions (Hayes and Wheelwright, 1984). Structural and infrastructural decisions are rearranged into many categories by various authors. Table I shows major categorizations by Skinner; Hayes and Wheelwright; Buffa; Fine and Hax, Miltenburg; and Slack and Lewis. These enumerations (Table I) have differed slightly from author to author but there is an essential agreement on those areas that are important for manufacturing strategy. Slack and Lewis (2009) argue that all the decision areas have both structural and infrastructural implications and cannot entirely be categorized into one. However, based on predominant orientation, we broadly place Slack and Lewis's "development and organization" area into infrastructural decisions and other remaining areas into structural decisions. This paper considers categorization of Miltenburg (2005) that consists of six decision areas. Some key decisions for each decision area are listed below:

(1) *PPC*. Key decisions include master production scheduling technique, materials requirement planning technique, inventory and production control technique, planning input, planning strategy and planning horizon.

(2) *Facilities*. The decisions pertaining to capacity, number and location of facilities are considered in this area.

(3) *Sourcing*. Policies towards suppliers' relationship and vertical integration are covered here.

(4) *Process technology*. It includes decisions related to machines, layout, process type, use of advanced technologies and quality and maintenance practices.

(5) *Organization structure and control*. This decision area covers organizational hierarchy, control and culture.

(6) *Human resource*. This decision area comprises policies about employees in manufacturing area such as skills, training, job expansion and performance appraisal.

Table I. Categorization of manufacturing decision areas

Skinner	Hayes and Wheelwright	Buffa	Fine and Hax	Miltenburg	Slack and Lewis
Structural					
Plant and equipment	Capacity Facilities Technology Vertical integration	Capacity; location Product/process technology Strategy/supplier integration	Capacity Facilities Process and technologies	Facilities Process technology Sourcing (suppliers and vertical integration)	Capacity (includes facilities) Supply networks Process technologies
Infrastructural					
Production planning and control Organization and management Labour and staffing Product design/ engineering	Production planning and control Quality Organization Workforce New product development Performance measurement systems	Strategic implications of operating decisions Workforce and job design Position of production system	Product quality Human resources Scope of new products	Production planning and control Organization structure and control Human resources	Development and organization

Sources: Adapted from Leong *et al.* (1990), Miltenburg (2005) and Slack and Lewis (2009)

2.2 Process specific decision choices in a job shop production system

As indicated by past studies, job shop uses customer order (Safizadeh and Ritzman, 1997; Miltenburg, 2005) as planning inputs and follows make-to-order (MTO) policy (Olhager *et al.*, 2001; Miltenburg, 2005) in master production schedule (MPS). Due to fluctuating level of customer demand, chase planning strategy is thought to be the most suited in job shop (Olhager *et al.*, 2001; Safizadeh and Ritzman, 1997). Further, the time-phased material requirement planning (MRP) is appropriate to schedule and track customer demand (Bhattacharya and Coleman, 1994; Olhager and Rudbergy, 2002). Olhager and Rudbergy (2002) point out that the company employing process layout (i.e. job shop) uses each resource or department as independent planning point. It is considered that the job shop carries high level of raw materials and work-in-process (WIP) inventory to decouple different stages of operations (Hill and Hill, 2009). But, Miltenburg (2005) argues that the amount of raw materials inventory should be low as products change from customer to customer. Safizadeh and Ritzman (1997) empirically found raw materials inventory to be high (42 days). Finished goods (FG) inventory is expected to be low in job shop as it uses MTO policy (Hill and Hill, 2009; Safizadeh and Ritzman, 1997). It is believed that set-up time is generally large compared to run time in job shop (Miltenburg, 2005). Few studies suggest that job shop achieves economy of scale by combining several customer orders as backlog (Ashton and Cook, 1989; Safizadeh and Ritzman, 1997). Safizadeh and Ritzman (1997) state that planning horizon for job shop is shorter due to high degree of uncertainty and complexity of customer demand.

Olhager *et al.* (2001) argues that job shop is likely to choose lead capacity strategy facilitating the company to use chase demand policy. Miltenburg (2005) states that the size of the facility in case of job is likely to be small. He claims that vertical integration in job shop involves one production stage having no forward/backward integration. Further, he adds that a large number of suppliers are involved as product varies from customer to customer. It is suggested that the process layout and general purpose machineries are appropriate to handle large product varieties in job shop (Hayes and Wheelwright, 1979a, b; Miltenburg, 2005). Zhang *et al.* (2006) recognize advance manufacturing technology (AMT) to be an important element in building a competitive production system that can deliver the product variety that the customer demands. Zhang *et al.* (2006) classify the use of AMT in product design, manufacturing, planning and integration. Das and Narasimhan (2001) indicate extensive use of AMT in product design for job shop due to degree of customization provided. There are chances of disconnection between various processes to maintain the independence of operations by keeping inventories and less use of automation (Slack and Lewis, 2009). Nahm *et al.* (2003) provide the list of five decision types in organization structure decision area and argue that organization structure may be partly affected by the firm's external environment. They find that the organizations that operate with a high degree of environmental uncertainty may decentralize decision making, rely less on formal rules and policies and flatten their hierarchies. According to Hill and Hill (2009) and Miltenburg (2005), the organization structure in job shop is likely to be flat. Operations are also decentralized for quick response to changes in customer needs (Miltenburg, 2005). Further, the workers with high skills are needed to facilitate such a change.

It is observed from the review that there are some studies on decision choices specific to job shop. It can also be seen that most of the studies pertain to PPC area.

2.3 Non-process specific decision choices

Some studies indicate that few other factors may influence decision choices irrespective of process choice of the production system. This paper identifies such factors from literature as follows.

Product complexity. Choe *et al.* (1997) argue that companies which align product complexity to business strategy would develop competitive advantage in the market. The product complexity considers factors such as product variety, product volume, end product complexity and end product experience (Kotha and Orne, 1989). It may be noted that the product complexity could be a major factor in determining the process choice. Choe *et al.* (1997) proposed a method for computing product complexity indices using the above factors. Authors (Bhattacharya and Coleman, 1994; Spring and Dalrymple, 2000; Garrido *et al.*, 2007) observe that decisions such as planning strategy, master planning schedule are related to product complexity. Bhattacharya and Coleman (1994) argue that high product complexity of the company requires chase planning strategy to be followed in PPC decision area.

Strategic orientation of manufacturing. Wheelwright and Hayes (1985) proposed a four-stage model to evaluate the strategic orientation of manufacturing. Accordingly manufacturing can be in one of the four stages in a continuum, where stage 1 means internally neutral and stage 4 means externally supportive role of manufacturing function. Barnes and Rowbotham (2004) operationalised the H-W four-stage model describing the strategic role of operations. Wheelwright and Hayes (1985) have suggested that companies in different stages exhibit different preferences in their decision choices. For instance, the companies in stages 1-3 use command and control method of workforce management while those in stage 4 use learning. Further, different decision areas of a company may not necessarily be at the same stage of development (Wheelwright and Hayes, 1985).

Despite its practical appeal and simplicity, assessment of a company's stage in H-W model is not an easy task (Hum and Leow, 1996; Avella *et al.*, 2001; Barnes and Rowbotham, 2004). Hayes *et al.* (1988, p. 351, Chapter 12, Figure 12-1) provide characteristics and practices of companies in stages 2 and stage 4 of H-W model on each of the decision area. Hum and Leow (1996) used these as criteria to place the electronic companies in Singapore at appropriate stages. This paper compares the policies of each case company with the characteristics of stages 2 and 4 companies outlined by Hayes *et al.* (1988). If these policies match with the characteristics of a particular stage (e.g. stage 2 or 4) then the company is considered to be in that stage. The company placed in stage 3 if its policies are more progressive than stage 2 and placed in stage 1 if the policies are less progressive than stage 2.

Competitive priorities. Hill and Hill (2009) define competitive priorities as order winners and qualifiers. Order winners are criteria that win the order while qualifiers are those that get's shortlisted by customer. It is believed that decision choices may have been influenced by order winning criteria (Safizadeh and Ritzman, 1997; Vickery *et al.*, 1999; Narasimhan and Das, 1999; Olhager *et al.*, 2001; Miltenburg, 2005).

Top management decisions. Some decision choices in areas such as capacity, size, location and vertical integration may not be related to choice of a process (Schmenner, 1979; Slack and Lewis, 2009) but to factors such as market, raw material sources and capacity of the company to invest. Schmenner (1979) lists several reasons for location decision that are non-process specific.

Size of the firm. Some studies (Cagliano and Spina, 2000; Swamidass and Kotha, 1998; Spring and Dalrymple, 2000) have found the size of the company, e.g. number of employees to be influencing other decisions. Swamidass and Kotha (1998) find that use of AMT in manufacturing is lower in smaller size firms than in larger firms. In organization structure and control decision areas, Vickery *et al.* (1999) empirically found that the size of the company is positively related to the number of layers, the span of control and nature of formalization.

2.4 Research framework

It is clear from the literature that some decision choices are process specific to the job shop, while some decisions may depend on factors such as product complexity, strategic orientation, order winning criteria, top management decision and size of the company. In practical situations, the presence of non-process specific factors gives rise to the possibility of alternative configurations of job production system.

Accordingly, an operational framework to study choices in manufacturing strategy decisions in a job production system is shown in Figure 1. This research framework considers six manufacturing decision areas containing various decisions called "decision types". Each decision type has a few possible alternative choices available for the company. A specific choice selected by the company is either affected by process choice or other non-process specific factors, as shown by the arrow in Figure 1.

3. Research methodology

Many authors have stressed the need for a case study research in the field of manufacturing strategy (Adam and Swamidass, 1989; Flynn *et al.*, 1990; Swamidass, 1991;

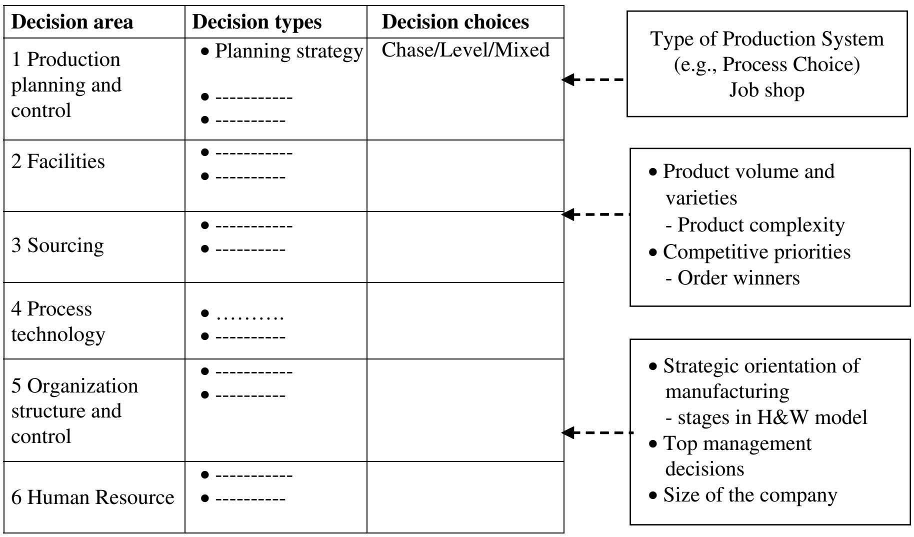

Figure 1.
A framework to study the choices in manufacturing strategy decisions in a job production system

Meredith, 1998; Dangayach and Deshmukh, 2000). The underlying aim of the case study research is to reduce the gap between the theory and practice by making the research useful to the practitioners. The purpose of the case study is not only to describe a situation but, more often, it is to understand how or why events occur (Yin, 1984). The findings obtained from the analysis will be grounded on empirical evidence. The paper conducts an exploratory study (Table I, McCutcheon and Meredith, 1993) to identify possible alternative configurations of job production system by investigating process specific and non-process specific decision choices using case study methodology.

3.1 Selection of case companies

The sample size in the case study methodology has a significant effect on the quality of the research (Yin, 1984). A few case studies make it difficult to generalize findings while too many make it difficult to study the level of the details required. There is no overall consensus on the ideal number of case study companies but there is a general agreement that anywhere between four and ten work well (Eisenhardt, 1989; Yin, 1984). Primarily, the selected case should fall in the boundary of what one wants to study and connect to the research questions than sampling logic (Eisenhardt, 1989; Yin, 1984). Overall, we visited seven companies but two companies were dropped as they failed to qualify some of the characteristics of the job shop. We started with two cases (cases A and B) and looked into the commonalities and differences of decision settings. Subsequently, three more companies (cases C, D and E) were sequentially considered. We observed a similar kind of pattern in the decision choices emerging out of the companies when they were grouped in terms of process specific decisions and some non-process specific decisions. Then it was felt that adding more companies is not likely to add any significant information for the purpose of this research and it was assumed that "theoretical saturation" has reached. The final sample included five manufacturing companies. The details of the case company's characteristics, products, order winners and size are provided in Table II. We have used alphabets to ensure the

Product	Case A Cold rolling mills rolls	Case B Automobile press die	Case C Machine part (job works)	Case D Castings	Case E Waste recovery heaters
Company size					
Sales (Indian Rs.) (million)	50	80	25	490	1,610
Number of employees	55	45	35	740	160
Order winners	Quality (conformance and durability), delivery	Quality (conformance and durability), delivery	Quality (reliability and durability), delivery	Quality (conformance), delivery	Quality (performance), delivery
Product complexity[a]					
1. Prodcut variety	Large (6)	Very large (7)	Very large (6)	Large (6)	Large (5.5)
2. Customization offered in each product	Customized (6)	Highly customized (7)	Highly customized (6.5)	Customized (5)	Customized (6)
3. Individual products volume (order size)	1-25 (6)	1-2 (7)	1-25 (5)	1-25 (5)	1-2 (7)
4. End product complexity (avg. no. of part in BOM)	Less than 5 (2)	10-15 (2)	Less than 5 (3)	Less than 5 (3)	250-300 (5)
5. End product experience (years)	20 (2)	17 (3)	10 (4)	20 (2)	20 (2)
6. Product simplicity	High (4.5)	Very high (5.5)	High (3.5)	Very high (5)	Very high (5.5)
Product complexity index (out of 42)	*26.5*	*31.5*	*28*	*26*	*31*
Product complexity[b]	High	High	High	High	High

Notes: [a]Using items proposed by Kotha and Orne (1989) and each item rated on seven point scale suggested by Choe *et al.* (1997); the rating for each item is provided in parenthesis; [b]product complexity of a case company is assumed to be high when its index is greater than 50 percent of maximum value of 42, i.e. 21 else it is low

Table II. Background of case companies

anonymity and confidentiality of the companies participated in this study. Companies are classified based on its size as small, medium and large. Company D is large with 740 employees, company E is medium with 160 employees and companies A-C are small with 35-55 employees.

All companies considered in our study satisfy the key characteristics of the job production system. These companies were willing to participate in this research and also found to be convenient for the researchers to visit. The typical characteristics of the job shop production system included a large number of product varieties in a very low volume as per customer requirement or specification (Miltenburg, 2005) and where similar kind of order does not get repeated (Hill and Hill, 2009).

3.2 Case protocol

One requirement for properly carrying out a case study is a protocol for information gathering (McCutcheon and Meredith, 1993). Case protocol is a necessary tool while conducting multiple case studies (Yin, 1984). A case study protocol was designed that included overview of the research, general information of the company, product information, product volume and varieties, customization offered, number of employees, turnover, experience in current product line and "order winners" competitive priorities. It also seeks information related to various decision choices made by manufacturing companies in six decision areas. A total of 54 decision types in six decision areas identified by Choudhari *et al.* (2010) are considered. The protocol also lists some questions to be asked during the visit and mentions sources for obtaining the required information. The detailed protocol is not included in the main text because of space limitation but is available from the authors upon request. However, the items covered in the case protocol are summarized in the Appendix.

3.3 Validity and reliability

The quality of the case studies is generally judged on the basis of various tests such as external validity, construct validity, internal validity and reliability (Yin, 1984). The manufacturing companies selected in the case sample (Table II) cover a good range of data in terms of product varieties, number of employees, etc. thereby enhancing the external validity of the findings. However, no empirical study offers certainty that its findings are valid for other populations. Direct observation of production system, asking information from more than one source (triangulation) and additional clarification improved the construct validity. Internal validity for research question was taken care by pattern matching and explanation building from available literature. Yin (1984) talks about case study protocol and development of case study data base as general ways of approaching the reliability problem. Issues on reliability were tackled by seeking information from more sources and by proper documentation of case protocol.

3.4 Data collection and tabulation

Our unit of analysis for the case study was company's production system. The first point of contact in the company was the head of production department or general manager of the company. We initially explained them the research objectives, details of information required and possible employees of the company required for interaction. The data was collected by semi-structured interview of the people who had knowledge of production system. Those who participated in this research are general managers and middle managers in production planning, production, quality, marketing, purchase and human resources. We visited the shop floor to get a feel of the actual production system. Often, interaction was done with the shop floor supervisors who also accompanied during our visit to the production facility. Additional information was sought by direct observation of production system, company documents and web site. On an average, two to three visits were made to each plant. Each visit lasted for three to 4 h. In case of ambiguity or the person being interviewed not being familiar, the information was clarified from more than two sources or higher authority or by seeking contact of the appropriate person.

In case of the data not getting triangulated, further discussion with higher authority was done and that information was considered final. Further, numerous telephone calls were made to seek any additional clarification. Data was tabulated where column titles are company names and row titles correspond to data items related to company profile, product complexity, decision choices, competitive priority, etc. The data collected on choices made by the five companies in each decision area are summarized in Tables III-VIII and discussed in Section 4. Competitive priorities (order winners) for all case companies were identified from discussion with key people in the companies.

Decisions types	Case A	Case B	Case C	Case D	Case E	Decision linked to
Planning inputs	Customer	Customer	Customer	Customer	Customer	Process specific choice
Master production schedule (MPS)	MTO	MTO	MTO	MTO	MTO	Process specific choice
Planning strategy	Chase	Chase	Chase	Chase	Chase	Process specific choice
Material requirement planning (MRP)	Time-phased	Time-phased	Time-phased	Time-phased	Time-phased	Process specific choice
Shop floor control	Push	Push	Push	Push	Push	Process specific choice
Raw materials (RM)	15 days	30 days	30 days	30 days	30 days	Process specific choice
Work-in-process (WIP)	60 days	20 days	20 days	60 days	60 days	Process specific choice
Finished goods (FG)	8 days	0 days	3 days	0 days	0 days	Process specific choice
No. of planning point	Many	Many	Many	Many	Many	Process specific choice
Set-up time	3 h	45 min	30 min	60 min	60 min	Process specific choice
Length of planning horizon for FG	30 days	120 days	30 days	30 days	90 days	Process specific choice
Planning process	Centralized	Centralized	Centralized	Decentralized	Decentralized	Size of company
Batching of backlog for planning	0	0	0	0	0	Process specific choice
Frequency of re-planning	30%	30%	25%	20%	30%	Process specific choice
Length of frozen schedule	7 days	30 days	7 days	7 days	30 days	

Table III.
PPC area

Decision types	Case A	Case B	Case C	Case D	Case E	Decision linked to
Capacity planning	Lead	Lead	Lead	Lead	Lead	T0op management decision
Size of capacity addition	Small pieces	Small pieces	Small pieces	Medium	Medium	Size of company
Size of facilities	Small	Small	Small	Large	Large	Top management decision
Location of facilities	Local place	Markets	Markets	Supply	Local place	Top management decision
Multi-plant strategies	–	Markets	–	–	Product	Top management decision
Number of facilities	One	Three	One	One	Seven	Top management decision

Table IV.
Facilities area

Decision types	Case A	Case B	Case C	Case D	Case E	Decision linked to
Vertical integration: stages	One	One	One	Two	Two	Top management decision
Vertical integration: breadth	Many (90%)	Many (95%)	Many (80%)	Many (95%)	Many (90%)	Top management decision
Vertical integration: degree forward	Nil	100%	Nil	Nil	Nil	Top management decision
Vertical integration: degree backward	Nil	Nil	Nil	Nil	Nil	Top management decision
Number of suppliers per item	Few 3	Few 2	Few 3	Few 3	Few 2-3	Process specific choice
Supplier involvement in problem solving and product development	Little	Little	Little	Medium	Medium	Stages in (H&W) model
Supplier responsiveness w.r.t. to changes in delivery schedule, volume and product mix	Average	Average	Average	Average	Average	Stages in (H&W) model
Supplier performance w.r.t. quality, delivery reliability	Average	Average	Average	Normal	Average	Stages in (H&W) model
Purchasing skill, e.g. technical capability to deal suppliers	Average	Average	Average	Average	Average	Stages in (H&W) model

Table V.
Sourcing area

They were asked about the background of some key decisions made by the companies to understand the rationale for some top management decisions.

One more factor considered in this research is the product complexity. Product complexity index for all the five companies were computed (Table II) using the method proposed by Choe *et al.* (1997). Accordingly, each item comprising product complexity (see Section 2.2) is rated on the likert scale. Product complexity of a case company is considered to be high when its index is greater than 50 percent of maximum value

Decision types	Case A	Case B	Case C	Case D	Case E	Decision linked to
Type of layout	Process	Process	Process	Process	Process	Process specific choice
Nature of machineries	General	General	General	General	General	Process specific choice
Use of AMT for product and process design, e.g. CAD, CAE	Nil	Extensive	Extensive	Extensive	Extensive	
Use of AMT for manufacturing, e.g. CNC, automatic material handling, GT robotic	Nil	Extensive	Extensive	Medium	Extensive	
Use of AMT for planning and control, e.g. MRP, bar code and EDI	Nil	Medium	Little	Little	Extensive	
Use of AMT for integration, e.g. CIM, ERP, LAN and WAN	Nil	Medium	Nil	Extensive	Extensive	Size of company
Degree of automation	Nil	Medium	Medium	Little	Medium	Process specific choice
Degree of coupling	Loose/separate	Loose/separate	Loose/separate	Loose/separate	Loose/separate	Process specific choice
Use of maintenance TPM and Kaizens	Little	Medium	Little	Little	Extensive	Stages in (H&W) model
Use of quality practices, e.g. SQC, QC, TQM	Little	Medium	Little	Little	Extensive	Stages in (H&W) model

Table VI.
Process technology area

of 42, i.e. 21, otherwise it is considered to be low. It is observed that the product complexity of all five cases is high with little variation from case to case. This made analyzing the relationships of decision choices with product complexity in this research difficult. One may suspect this to be true for job shops in general. It appears that the high product complexity is one of the attributes that defines job shop production system similar to high variety and low volume.

4. Case analysis and discussion

We first conduct with-in case analysis followed by cross-case analysis. Specific findings from the analysis are shown in the last column of respective decision areas in Tables III-VIII.

4.1 With-in case analysis

Each case starts with the background of the company and then discusses the decisions determined by competitive priorities (order winner) and preferences and considerations of the top management. These relationships were arrived based on in-depth interview with company people and support from the literature. All five case companies manufacture customized products. The products are required in low volume and repeat order for the same configuration is rare.

Case A. Company A manufactures rolls, a component of cold rolling mills. The quality (conformance and durability) of rolls has effect on quality of sheets produced. Hence roll quality is an order winner in the market in addition to the delivery.

Table VII. Organization structure and control area

Decision types	Case A	Case B	Case C	Case D	Case E	Decision linked to
Locus of decision making authority (delegation)	Centralization	Decentralization	Centralization	Decentralization	Decentralization	
No. of layers	Few (flat)	Few (flat)	Few (flat)	Medium	Medium	Size of company
Level of horizontal integration	High	High	High	Low	Low	Size of company
Spans of control	Narrow	Narrow	Narrow	Wider	Wider	Size of company
Nature of formalization	Minimum	Minimum	Minimum	Minimum	Minimum	Process specific choice
Level of communication	Average	Fast/easy	Average	Fast/easy	Fast/easy	

Decision types	Case A	Case B	Case C	Case D	Case E	Decision linked to
Recruitment and selection	Casual	Particular	Particular	Particular	Particular	
Level of skill for worker	Skilled 80%	Skilled 80%	Skilled 70%	Skilled 70%	Skilled 90%	Process specific choice
Job specialization/ nature of job	Broad > 3	Broad > 3	Two to three type	Fixed and explicit one type	Fixed and explicit one type	Size of company
Job expansion, e.g. enlargement, enrichment, rotation, empowerment	Medium	Little	Medium	Little	Little	Stages in (H&W) model
Ergonomics and work methods standards	Medium	Medium	Medium	Medium	Extensive	
Performance appraisal	Individual/ short term	Individual/ short term	Individual/ short term	Individual/ short term	Individual/ short term	
Training and development	Medium	Medium	Medium	Little	Extensive	
Sharing information	Little	Extensive	Little	Medium	Extensive	
Top management commitment	Medium	Extensive	Medium	Medium	Extensive	

Table VIII.
Human resource area

Chrome plating process for rolls is considered critical for long life and durability. The company has developed competency in chrome plating process over a period of time and they use skilled workers to improve the quality of rolls. The owner said:

> We generally recruit non-technical people and let them learn the skills while working on the shop floor with the trained people even if it takes a long time for them to reach high level of skills. This is our employee retention policy.

Due to limited financial capability, the company started a small manufacturing facility with 55 employees in a small industrial belt where the owner resides. Considering good growth in steel industry, few competitors in their segments and fluctuating level of customer demand, the company follows a lead capacity strategy. The company procures small accessories from vendors but makes 90 percent of components in house.

Case B. Company B has 45 employees and is a part of an industrial group. It manufactures customized dies for heavy presses for their sister companies that produce automobile components. The planning manager commented "This unit is not considered as profit center but we provide good quality product to our sister companies to help them gain competitive advantage in the market". Typically dies needed are one or two in numbers. The dies play a crucial role in producing good quality automobile components. Thus, quality (conformance and durability) of dies along with delivery are order winning criteria. The company has made extensive investment in skilled workforce and AMT to meet the required order winning criteria.

The plant is located in a big industrial hub of automobile manufacturers and component suppliers. There are two similar facilities at different locations to meet the demand of their sister plants completely. A lead capacity strategy is used. The company makes 95 percent of the required components for press dies in the plants itself.

Case C. Company C is a small firm with 35 employees. The company does job work for local manufacturing companies which need repair and/or replacement of their worn out or broken down machine parts. Quality (reliability and durability) of repaired components and delivery are order winning criteria. One of the supervisors stated "Our flexibility and ability to manufacture any component within specified delivery time is a key to be successful in this market". The company has made investment in AMT in design and manufacturing to support this goal.

There is ample demand in this market. Therefore, the company has made investment in resources to follow lead capacity strategy. The key factor in choosing the location of the plant was nearness to the market. The company produces the components in house to the extent of 80 percent.

Case D. Company D has 740 employees and is a part of a large conglomerate group. It manufactures castings that are supplied for a variety of applications. The castings are produced in low volume weighing from 500 to 13,000 kg. Quality (conformance) and delivery are key order winners in this market. The processes such as pattern making, moulding are labor intensive and skilled jobs. Therefore, the company has invested in AMT in product design area and employs skilled workforce. The general manager of this company said:

> Many of our skilled employees are local people who are not willing to migrate to other places. Since this region is not much industrialized, we could retain them over a long period of time.

The market is growing rapidly with not many competitors allowing the company to follow a lead capacity strategy. Location of the company is chosen for easy access to raw materials and cheap labors. Most orders require only casting while a few required further machining operations. The company performs 95 percent of casting work in house.

Case E. Company E is a large firm with 160 employees and manufactures waste recovery heaters for various applications in process industries such as petrochemical and cement. The management has taken a lot of initiatives to implement world best practices and to improve their products and production processes. Quality (performance) and delivery are order winning criteria in this market. As each product requires high degree of customization, highly skilled people are required. Extensive investment in AMT, development and training of skilled workforce are undertaken.

A lead capacity strategy through investment of manpower and machineries is used by this company as the market is growing and there is little competition. The owner located the plant in his hometown but now the place has been developed into an industrial area. Six similar facilities are set up and each is dedicated to produce a particular line of product. The major production stages are two: fabrication of components and assembly. The company makes 90 percent of components in the plant and the remaining is outsourced.

The following are important observations from with-in case analysis.

In general, job shop produces customized products in low volume and it sells product flexibility to the customers. Our case study finds delivery of product to be important, demand to be fluctuating and existence of few competitors in their respective markets. Therefore, these companies use lead capacity strategy. Olhager *et al.* (2001) argues that job shop is likely to choose lead capacity strategy facilitating chase demand strategy.

Miltenburg (2005) states that size of facility in case of job shop is likely to be small. We observe that the size of the company varies from small to large facility in job production system. The decision on size of the facility is influenced by the company's financial ability to invest. Location decision of the case companies is based on raw material availability, nearness to market and owner's preference. Multi-plants strategy and number of facilities are decided considering nearness to the market and focus of product. Vertical integration is preferred by the case companies if it provided certain competitive advantage and also the company had the expertise in it. In some instances, the choices such as use of AMT and lead capacity strategy are made to support the order winning criteria of the companies.

4.2 Cross-case analysis

Consistent with rigor in case study research, our analysis focused on finding patterns of commonalities and differences across case companies (McCutcheon and Meredith, 1993). This is achieved by comparing data across columns/cases (Tables III-VIII) for each of the decisions. The decision choices which were the same for all five companies were considered to be process specific. In cases where decision choices were not the same, relationships of non-process specific decisions with factors such as strategic orientation of manufacturing (stages in H-W model) and size of the company were identified. Decision choice is considered one at a time and the companies were grouped based on different decision settings. Subsequently, possible link of this decision setting with non-process specific factors was examined using support of literature or through conceptual reasoning as the case may be. Further, all the five case companies are observed to have high product complexity.

Production planning and control. Job shop is expected to use customer order as planning inputs (Safizadeh and Ritzman, 1997; Miltenburg, 2005) and always follow MTO policy (Olhager *et al.*, 2001; Miltenburg, 2005) in MPS. All the case companies considered in this study selected customer order and MTO policy choices and are thus consistent with the literature. Bhattacharya and Coleman (1994) argue that high product complexity require chase production strategy. Safizadeh and Ritzman (1997) find that chase is most suited for job/batch shop production system to respond to fluctuation in demand. In line with these studies, all the case companies in our cases follow chase strategy and also have high product complexity. A time-phased MRP allows a wider range of custom-built products (high product complexity) and better product-mix flexibility (Bhattacharya and Coleman, 1994; Olhager and Rudbergy, 2002). With regard to this aspect, it is observed that all the case companies follow time-phased choice in MRP. Choices for decision types seem to be identical for different case companies namely A-E. This phenomenon could be attributed to high product complexity of various case companies considered in this study.

In shop floor control, the study by Bhattacharya and Coleman (1994) found pull-type to be generally used for high volume products while push-type of system to be more suited for planning low volume products. In our study, all the case studies produce low volume product and therefore use push-type system. This finding is consistent with the previous studies (Bhattacharya and Coleman, 1994; Olhager and Rudbergy, 2002). Centralized or decentralized planning process is one of the pertinent issues for production system. Our observations show that smaller companies (cases A-C) follow centralized planning policy while larger companies (cases D and E) follow decentralized planning policy. The reason for this seems to be convenience of planning and thus depends upon the size (no. of employees) of the company. Olhager and Rudbergy (2002) observed more number of planning points for a plant that uses process layout (e.g. job/batch shop). The number of machines can be interpreted as number of planning points if these are actively planned as independent resources. All the companies considered in our study use process layout and manage machines as independent resources for planning and thus results in more number of planning points.

Contradicting view exists on the number of days of raw materials being kept as inventory in job/batch shop. Miltenburg (2005) argues that it should be of low level as product changes from customer to customer. However, Safizadeh and Ritzman (1997) empirically found it to be high (42 days) in their study. Inventory level of raw materials is approximately 30 days for all the companies considered in our study. In our view, the number of days of inventory would depend upon raw materials being common across product varieties as customization happens after processing stage. It is considered that job shop carries more WIP than line/flow shop because of long production lead time and the desire to decouple different operations (Safizadeh and Ritzman, 1997; Hill and Hill, 2009). The WIP inventory of cases being studied here ranges from 20 to 60 days in order to decouple various processes and hence termed as high. In job shop, FG inventory is expected to be low as production is believed to be against customer order (Hill and Hill, 2009; Safizadeh and Ritzman, 1997). This is true in all the cases considered except when FG inventory remains on shop floor due to delay from customer approval and clearance for shipment.

Sometimes, companies achieve economy of scale by combining several customer orders as backlog (Ashton and Cook, 1989; Safizadeh and Ritzman, 1997). In case of job shop (cases A-E), none of the cases uses such a policy as order for similar products are not assured from various customers. Generally, customer orders are processed in sequence as and when resources become available. In job shop, set-up time is believed to be large compared to run time and this is the case with all the companies studied here. Olhager and Rudbergy (2002) suggest the suitability of time-phased approach MRP when set-up time is large. Our case data supports this relationship. Safizadeh and Ritzman (1997) state that planning horizon for job/batch shop is likely to be longer (210 days) than that of line/continuous shop due to more uncertainty of customer demand in the former case. In our case studies, cases A-E (30-120 days) have shorter planning horizon. Safizadeh and Ritzman (1997) further state that less backlog and shorter planning horizon have positive effect on customer service. Customer service such as delivery speed and reliability are important criteria in all the cases considered in our study. This may have relation to zero backlog and shorter planning horizon. We did not find any pattern in the length of frozen schedule for the companies in our case studies. However, interaction with company people makes it clear that this is generally decided as per convenience. In our cases it varies from 1 week to 1 month. Due to variation in demand and work content in customer order, it is expected that job shop has more re-planning flexibility in production plan. In our case studies, companies have 20-30 percent re-planning flexibility in production plan consistent with the observation made above.

Facilities. It appears that increment in capacity addition is in accordance with the size of the company. Companies A-C add capacity in small quantities (i.e. few machines/labors) while companies D and E add in medium quantities (i.e. more machines/labors). As discussed in with-in case analysis, other facility decisions namely capacity strategy, location, size of the company, multi-plant strategy, etc. are decided by top management for reasons such as raw material availability, market reach, ability to invest and fluctuations in demand.

Sourcing. Sourcing decision area includes elements of vertical integration and supplier relationship. Vertical integration decisions have been discussed in with-in case analysis. It is accepted in supply chain literature that better relationship with supplier has positive impact on delivery speed, delivery reliability and flexibility (Narasimhan and Das, 1999). All cases in our study use on an average 2-3 suppliers per item rather than many suppliers as given in the literature (Miltenburg, 2005). The argument is that product is generally produced specific to customer. Our observation shows that even though the product is customized, similar kind of raw materials are used by all case companies facilitating customization in latter stages.

As raw materials are common, there is little involvement from suppliers for the companies A-C. However, companies D and E involve suppliers to some extent in problem solving whenever critical components are procured. The current practices of companies are towards cost minimization and short term contract than having collaborative partnership and supplier capability enhancing. All cases studied here have average level of supplier responsiveness, supplier performance and purchasing skills except case D that seems to have quality problem. The supplier policies of the case companies suggest that they are in between stages 1 and 2 of H-W model. Thus, there is potential to improve in this area and move to higher stages.

Process technology. Job shop produces a large number of varieties in low volume and therefore the flow of product is not fixed. Process layout and general purpose machineries are appropriate to handle such large product varieties effectively (Hayes and Wheelwright, 1979a, b; Miltenburg, 2005). All case companies in our study use process type layout using general purpose machineries capable of doing many operations.

Zhang *et al.* (2006) categorized AMT into four types based on its use:

(1) product design technologies (i.e. CAD, CAE, CAPP, etc.);

(2) manufacturing technologies (i.e. CNC, CAM, FMS, etc.);

(3) planning and control systems (i.e. MRP, MRPII, EDI, etc.); and

(4) integration technologies (i.e. ERP, LAN, WAN, etc.).

Das and Narasimhan (2001) indicate extensive use of AMT in product design for job shop due to the degree of customization provided. However, Swamidass and Kotha (1998) found the existence of positive relationship between size of the company and three other AMT dimensions mentioned above except product design technologies. In other words, except for product design technologies, AMT use is lower in firms of smaller size than in firms of larger size. Except case A, case companies B-E use AMT in product design extensively and hence not related to company size in anyway. Further, we do not find that size is related to the use of AMT in either manufacturing or planning. We observe that case A uses only traditional machineries for manufacturing, case D uses AMT at medium level while other companies B, C and E use AMT very extensively for manufacturing. Similarly, in case of AMT in planning, case E uses AMT extensively, case B uses it at medium level and cases A, C and D use at very little level. However, we find the use of AMT in integration is related to size of the company as larger companies D and E use it (ERP) extensively, smaller company B uses at medium level and companies A and C do not use it at all.

Due to large product variety and process kind of layout, it would be difficult to automate the material handling in job shop. Case D uses less automation for loading and unloading of parts on CNC with single operations. Cases B, C and E use medium level of automation as CNC can perform multiple operations in addition to loading and unloading. Human intervention is required in moving product from one workstation to another. Thus, automation is limited to mainly processing, loading and unloading activities and to some extent related to the use of AMT in manufacturing. There are chances of disconnection between various processes in process layout in order to maintain the independence of operations (Slack and Lewis, 2009). This is supported by our case studies as workstations are loose/separated to maintain the independence of operations.

Use of quality (e.g. SQC, QC, TQM) and maintenance (e.g. TPM, Kaizen) practices in cases A, C and D are low, medium in case B and extensive in case E. The company E implemented various quality programs such as Kaizens, TQM, etc. The company B improved process capability by using advanced manufacturing technology. Other companies A, C and D have not developed policies for such quality programs and efforts are made to just meet the required quality. Thus, the strategic orientation of companies A, C and D is stage 1, company B is stage 2 and company E is stage 3 of H-W model for quality and maintenance practices.

Organization structure and control. The *locus* of decision making authority is the degree to which decisions are passed to lower level of organization. To quickly respond to the customer need, operations in job shop are decentralized (Miltenburg, 2005). No specific pattern was found for this decision. The number of layers in hierarchy is the degree to which an organization has many (hierarchical) versus few levels (flat) of management (Nahm *et al.*, 2003). Organization structure in job shop is likely to be flat as per Hill and Hill (2009) and Miltenburg (2005). The findings of Vickery *et al.* (1999) show that the number of layers is positively related to the size of organization and negatively related to the product customization. It can be observed from our case data that the number of layers is influenced by the size of the firm more than the product customization. Small companies (cases A-C) have three to four layers while the large companies like D and E have five to six layers.

Low level of horizontal integration means that the departments and workers are functionally specialized while the high level of horizontal integration means that they are integrated in their work, skills and training (Nahm *et al.*, 2003). Companies A-C are highly integrated and work as coordinated teams while in the case companies D and E, tasks of workers are confined to specific areas indicating low level of integration. This indicates that it is related to size. Therefore, smaller companies have high level of horizontal integration. Span of control of the supervisor is said to be narrow if more number of subordinates report to him/her (Vickery *et al.*, 1999). Vickery *et al.* (1999) empirically found that the span of control is positively related to the size of organization. Companies A-C have narrow span of control wherein many subordinates report to the authorities of higher level. However, companies D and E have wider span of control as very few subordinates report to the authorities of higher level. It is apparent from the case pattern that span of control is also related to the size of the firm and the number of layers in the firm.

The nature of formalization is the degree to which the worker is provided with rules and procedures that deprive versus encourage creative, autonomous work and learning (Nahm *et al.*, 2003). Vickery *et al.* (1999) found that the nature of formalization is positively related to the size of the organization and product customization. In our case studies, all the companies provide sufficient flexibility to the workers. The cases do not support the correspondence of the size of the firm with the nature of formalization while the case companies having high product complexity (product customization) can be attributed to the minimum formalization. The level of communication is the degree to which vertical and horizontal communication is slow, difficult and limited versus fast and easy (Nahm *et al.*, 2003). All case companies indicated that they have average to fast and easy communication among their employees. This is due to the size of companies being small in case of A, B and C while use of information technology facilitating this in all other cases.

Human resource. Specific decisions in this area are related to the policies about employees in the manufacturing area such as skills, training, job expansion and performance appraisal (Miltenburg, 2005).

As product changes from customer to customer, workers with high skills are needed to facilitate such changes (Miltenburg, 2005). In our case companies, though there is mixed use of skilled and semi-skilled workers, proportion of skilled workers is more than 70 percent. Generally, semi-skilled workers assist skilled workers for non-critical services such as loading, unloading and material handling. It appears that higher use of general purpose machinery will require more skilled people. The workers in today's manufacturing environment are usually required to be cross-trained to understand processes better and be responsive to changing production needs (Nahm *et al.*, 2003). Workers in companies A-C are trained to do more than three tasks. However, in companies D and E, the workers have explicitly one to two jobs. This shows that the larger companies generally have explicit job definition while smaller companies expect their workers to do many jobs.

The level of job expansion in cases A and C is moderate while that for the other companies is very less. Human resource practices in areas, such as ergonomic, performance appraisal, training and development, sharing information and top management commitment of cases E and B are progressive towards developing competence while the other companies like A, C and D are largely of command and control type. The case companies E and B can be broadly placed in stage 3, cases A and C in stage 2 and D in stage 1 of H-W model in human resource decision area.

5. Conclusions and future work

Job production system mainly provides product differentiation and innovation in the market. The present paper illustrates case studies of five manufacturing companies employing job production system. It was observed that the product complexity of all five case companies was high with little variation from case to case. This is consistent with the study of Choe *et al.* (1997) where they find positive correlation of product differentiation and innovation with the product complexity. Further, it may be possible to differentiate job, batch and line production system based on product complexity values leading to the following proposition:

> *P1.* A company employing a job production system is likely to have a different range of product complexity than the batch and line production systems.

This exploratory research uncovers the process specific decision choices for a job production system. It also provides the relationship of the non-process specific factors such as competitive priorities (order winner), strategic orientation of manufacturing (stages in H-W model), top management decisions and size of the company with decision choices.

A large number of decision choices, mostly in the PPC and process technology areas were found to be similar for all the case companies. They are, planning inputs, MPS, planning strategy, MRP, shop floor control, inventory level, number of planning points, set-up time, frequency of planning, length of planning horizon and batching of backlog for planning in the PPC area and the type of layout, nature of machineries, degree of automation and the degree of coupling in the process technology area. Further, few decisions such as level of worker skill, nature of formalization and the number of suppliers belonging to the other decision areas were also found to be process specific. Some of the above findings are new to the body of literature:

P2. A company employing job production system is likely to exercise different choices in the decisions mentioned above for PPC and process technology areas than those exercised by batch and line production systems.

The decisions in the facility and sourcing areas are usually influenced by the considerations of the top management and thus the top management needs to be conscious of the strategic consequences of such decisions. Capacity strategy, size of the plant, number of facilities, location and vertical integration are such decisions found from case analysis. The most predominant reasons for facility decisions are financial ability to invest, raw material availability and nearness to market. Vertical integration is preferred by the companies only when it provides certain competitive advantage in the market.

The case companies in the different stages of H-W model were observed exhibiting different preferences in their decision choices largely in sourcing, process technology and human resource decision areas. This assessment can help the management for determining the scope for further improvement and accordingly develop the action plan. For example, an action plan such as TPM, TQM and supplier involvement to bring the company in higher stages of H-W can improve their competitiveness. Thus, it is possible that a job production system can move to a higher stage of H-W model to achieve better performance and competitive advantage:

P3. The job shops in higher stages of H-W model should outperform the ones that are in the lower stages.

Similar to the previous studies, this research also finds that the size of the company influences many decisions. Most of the decisions are from organization structure and control area. The decisions influenced by the size of the company are, number of layers, level of horizontal integration, the span of control, job specialization, planning process, capacity addition and the use of AMT in integration:

P4. A large job shop is likely to exercise different choices in the above listed decisions than a small job shop.

The findings of this paper can help practitioners understand the configuration of decisions in a job production system. It also conveys to the manager, the need for process specific settings while designing the production system. Since this research is based on five case companies, its findings should be generalized to large population with care. The current paper does not consider the link between performance of case companies and decision choices and this can be another limitation of this study. Thus, there is a scope for studying relationship between decision choices and performance in terms of competitive priorities. There are a number of other avenues for further empirical research. In particular, our research framework can be validated using a different sample of case companies. Further, usefulness of framework can be strengthened by undergoing sector specific studies in the job production system. Similar kind of studies can be conducted for other production systems such as batch, line and continuous system. Research can also be extended to testing and validating the research findings and propositions of this paper with the help of a large-scale questionnaire survey.

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Further reading

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Appendix

Table AI.
Items contained in case study protocol

Background of research...
Research objective...
Research framework... (Figure 1)

Section	Items	Possible source of data	Details collected	Reference
I	General information	Company web site, brochure, general manager/managing director	Location, main business, total number of employees in production system/unit, last year sales	Table II
II	Market characteristics	Top management/general managers (production, marketing or sales)	Customers, competitors, order winner and order qualifier competitive priorities	Table II
III	Product and process characteristics	Company web site, brochure, general manager (production), shop floor visits	Product variety, layout of production facility (process/product/cellular), material flow	Table II
IV	Product complexity	General manager (production)	Product variety, customization offered in each product, individual products volume (order size), end product complexity (avg. no. of part in BOM), end product experience (years), product simplicity	See, Table II: product complexity
V	Decision area, decision type and decision choices	Top management manager (production, purchase, quality, personnel), production planning people, shop floor visits, organization chart	Related to choices selected in each decision type of all six decision areas, i.e. PPC, facilities, sourcing, process technology; organization structure and control and; human resource	Tables III-VIII

Note: Above information is the summary of expanded version of case study protocol used for the data collection

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